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CLAIMS

What is claimed is:

1. (currently amended) A Machine for Production of Granular Silicon comprising:

10 a heating section located below a reacting section; where said heating section ~~can consist of~~ comprises one or more tubes heated by one or more heaters

 a mechanism that pulses silicon granules back and forth between the heating and reacting sections ;

15 at least one separate injection of means for injecting silicon containing gases; and

at least one separate injection means for injecting non silicon containing gases and

20 a heating means to heat the non silicon containing gases above the a reaction temperature; and

~~cooling each injection location of the silicon containing gases;~~

2. (currently amended) ~~a~~ A machine of claim 1 where there are multiple stages; a 1st stage each one consisting of comprising a heater section, and a reaction section, a granule pulsing mechanism, a separate gas injection means for
25 injecting silicon containing gases, a separate injection means for injecting non silicon containing gases and a heating means to heat the non silicon containing gases above the a reaction temperature and at least one additional stage comprising at least a heater section, a reaction section and a gas injection means. where ~~each reactor section has one or more injection nozzles for gases~~
30 ~~which promote additional reaction, in the silane reactor the gas to the reaction~~

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5 ~~section would be silane, for the hydrohalosilane, e.g. trichlorosilane or~~
~~tribromosilane reactor the gas to the reactor section could be the hydrohalosilane~~
~~alone, hydrogen alone or a combination of the two~~

3. (currently amended) aA machine of claim 1 or 2 which further
comprising the recovery of heat from the granules by direct contact with a high
10 purity gas, which has carbon and oxygen containing contaminants below 1
ppmw and preferably below 10ppbw and which can be non-silicon depositing or
reacting gases: such gases can be selected from a 1st group consisting of
hydrogen, helium, argon, nitrogen and mixtures thereof, or from a 2nd group
consisting of silicon tetrachloride and silicon tetrabromide but not mixtures of the
15 second 2nd group and hydrogen. and must be low in carbon and oxygen
containing contaminants, such as oxygen, water, carbon monoxide, carbon
dioxide and methane, which contaminants must be below 1 ppmw and
preferably below 10ppbw. Gases such as silicon trichlorosilane and silane are
not usable because they decompose, hydrogen chloride, hydrogen bromide or
20 mixtures of gases, which react such as a silicon tetrachloride, and hydrogen
mixture are not usable because they can react with the granules

4. (currently amended) aA machine of claim 1 further comprising a heat
exchanger in which the silicon containing gases are heated by hot liquid or
condensing vapor maintained within a temperature range which cannot cause
25 decomposition of the gases; which temperature range is typically between 200-
400°C but more particularly between 300-350- 360°C.

5. (currently amended) A machine of claim 1 further comprising a sieving
device, operated either continuously or in batches, by which the silicon granules
are sieved using one or more sieves manufactured from non contaminating sieve
30 material and undersized granules returned to reactor; where the
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5 ~~noncontaminating sieve material is selected from materials which contain silicon~~
the group consisting of single crystal silicon, polycrystalline silicon, silicon oxide,
silicon nitride, silicon oxynitride, and silicon carbide and mixtures thereof where
the contaminants in the abradable surfaces are low in contaminants, such as
~~boron, phosphorus, aluminum, arsenic, iron, copper and other metals, such~~
10 ~~contaminants will typically be below 1000 ppmwt and preferably below 100~~
~~ppmwt.~~

6. (currently amended) A machine of claim 1 further comprising an
optional feedstock recovery section; where hydrogen is injected in the heating
section, a silicon containing gas selected from a 1st group consisting of
15 trichlorosilane dichlorosilane, tribromosilane, dibromosilane, triiodosilane,
diiodosilane and mixtures thereof is injected via the separate injection means for
silicon containing gas in the reacting section and a silicon quadratetrahalide
selected from a 2nd group consisting of such as silicon tetrachloride, or silicon
tetrabromide and silicon tetraiodide is injected after the reactor section, mixed
20 with the reactor effluent then quenched at an optimal temperature to recover
silicon hydrohalides hydrohalosilanes selected from the aforesaid 1st group such
as trichlorosilane, and dichlorosilane, residual silicon tetrahalides selected from
the 2nd group and hydrogen.

7. (currently amended) A machine of claim 1 further comprising one or
25 more cooled joints between external equipment and the reactor which transmit
hot gases or solids and which are cooled using localized, one or more,
microchannels positioned to primarily cool the immediate area around the
connection to the reactor and/or the seal area of the connection to the external
equipment. elastomeric O-ring to a temperature such that decomposition of the
30 O-ring or increased permeability of the o-ring to oxygen, water and carbon
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5 ~~dioxide does not cause significant contamination without excessive heat loss,~~
such temperature is typically 25-300 C and preferably 50-150 C for o-rings made
from high purity fluorocarbon o-rings such as Viton, Kalrez and Teflon

8. (currently amended) A machine of claim 1 ~~one or two~~ where there is
further comprising external flow control of each said injection point means, such
10 flow control may be either direct with flow control of each nozzle said means
done independently, or indirect by means of a flow distribution device such as a
manifold or a combination of the two where some nozzles of the said injection
means are ganged in groups.

9. (currently amended) ~~a~~ A machine of claim 1 ~~8~~ where the instantaneous
15 flow of gases into the reactor through one or more of the injection means is
varied periodically shape of the pulse and/or the distribution of flow between said
injection means ~~nozzles may be~~ is adjusted to control the generation of new
particles without changing the total flow averaged over 1 minute.

10. (currently amended) ~~a preferred variation of claim 8~~ A machine of claim
20 4 where the flow of silicon containing gas to each nozzle one or more of the
separate injection means for silicon containing gas is controlled before the heat
exchanger ~~heater/s~~ and an even more preferred option where multiple separate
flows of the silicon containing gas are heated in the same heater heat
exchanger.

25 11. (currently amended) ~~a preferred combination of the above claims for~~
~~the use of silane as a feedstock, A machine of claim 2,~~ where there are ~~two or~~
more stages; high purity hydrogen is used for the non silicon containing gas to
the first stage ~~heating section~~ and silane is injected via the separate injection
means for silicon containing gas in all the stages. ~~for the cooling of the granular~~
30 ~~silicon and for return of undersize granules to the reactor; the sieving device is~~

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- 5 made from high purity quartz tubes and polycrystalline silicon sieves, the feedstock recovery system is not used; cooled joints are used for all the inlets and outlets of the reactor; the silane heat exchanger uses a condensing vapor maintained in the temperature range 340-360 C and each gas injection location is independently controlled.
- 10 12. (currently amended) a preferred combination of the above claims for the use of trichlorosilane, and/or dichlorosilane as a feedstock, A machine of claim 2, where there are; two or more stages; high purity hydrogen is injected in used for the non-silicon containing gas to the first and subsequent stages heating section and to the second reacting section, for the cooling of the granular silicon
- 15 and for return of undersize granules to the reactor; the sieving device is made from high purity quartz tubes and polycrystalline silicon sieves, a silicon containing gas selected from a 1st group consisting of trichlorosilane dichlorosilane, tribromosilane, dibromosilane, triiodosilane, diiodosilane and mixtures thereof is injected via the separate injection means for silicon containing
- 20 gas in the 1st stage and further comprising a final feedstock recovery system is used and where a silicon tetrahalide selected from a 2nd group consisting of silicon tetrachloride, silicon tetrabromide and silicon tetraiodide is injected, mixed with the reactor effluent then quenched at an optimal temperature to recover gases from the prior 1st group, residual silicon tetrahalides from the prior 2nd
- 25 group and hydrogen, to cool the effluent from 1100 C to 900 C and hydrohalosilanes, for recycle; cooled joints are used for all the inlets and outlets of the reactor; the chlorosilane the above said heat exchanger uses a condensing vapor maintained in the temperature range 340-360 C and each gas injection location is independently controlled

5 13. (currently amended) ~~a variation of claim 1,2,11 or 12~~ A machine of claim 1 where the heater section is of smaller diameter than the reactor section above it and connected by a tapered section, angle of said tapered section to be between 10 and 80 degrees from the vertical and preferably between 30-60 degrees from the vertical.

10 14. (currently amended) ~~a variation of claims 1,2,11,12 and 13~~ A machine of claim 1 where the heaters used in the heating sections are selected from the group consisting of ~~may be~~ resistance heaters, inductive RF heaters, microwave heaters, lamp heaters or lasers but are preferably resistance heaters.

15 15. (currently amended) ~~a further variation of claims 1,2,11,12 and 13~~ A machine of claim 6 where a high efficiency cyclone is used after the injection of the silicon tetrahalide to remove silicon dust from the effluent gases and to provide residence time for the mixing and reaction of the silicon tetrahalide with from the reactor effluent and the silicon dust to improve the feedstock recovery ~~system when this is used~~ of the said silicon hydrohalosilanes and tetrahalides.

20 16. (currently amended) ~~a yet further variation of claims 1,2,11,12 and 13~~ A machine of claim 1 where a silicon etching gas or mixture of gases may be injected through one or more nozzles of the injection means for the purpose of etching wall deposits from all or part of the reactor, such where the gases may be elemental halides such as is selected from the group consisting of chlorine, or
25 bromine, iodine, hydrogen halides such as hydrogen chloride, or hydrogen bromide, hydrogen iodide, or combinations a mixture of hydrogen and silicon tetrahalides such as silicon tetrachloride, a mixture of hydrogen and or silicon tetrabromide, a mixture of hydrogen and silicon tetraiodide and mixtures thereof.

30 17. (currently amended) ~~a additional improvement to the above claims~~ A machine of claim 1 where the reactor is supported upon a weigh cell, capable of
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5 both weighing the reactor and its contents and of measuring the intermittent force
exerted by the pulsing gas granules and where the connections to and from the
reactor are flexible enough to allow the slight deflection required by the weigh
cell, said deflection to be less than 1mm and preferably less than 0.5mm, and
the thermal expansion of the reactor relative to the support structure, said
10 thermal expansion to be less than 1" (25mm) and preferably less than 1/4"
(6mm).

18. (currently amended) ~~a further variation on the above claims~~ A machine
of claim 1 where all or a portion of the non silicon containing gases are heated to
a temperature below the reaction temperature outside the heating section then
15 heated to a temperature above the reactioner temperature inside the heating
section prior to entry to the reactinger section.

19. (currently amended) ~~a yet further variation of claims 12 and 13~~ A
machine of claim 2 where at least one of the second and subsequent stage
heating sections does contains some residual silicon dust and/or silicon
20 containing gases from the first stage reactinger section that can form a wall
deposit.

20. (canceled)